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PERCEIVED ORIENTATION OF A RUNWAY MODEL IN NONPILOTS DURING SIMULATED NIGHT APPROACHES TO LANDING

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JULY 1977

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Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Office of Aviation Medicine
Washington, D.C. 20591

NOTICE

Technical Report Documentation Page

1. Report No. FAA-AM-77-12	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PERCEIVED ORIENTATION OF A RUNWAY MODEL IN NONPILOTS DURING SIMULATED NIGHT APPROACHES TO LANDING		5. Report Date JULY 1977
		6. Performing Organization Code
7. Author(s) Henry W. Mertens		8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, Oklahoma 73125		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D.C. 20591		14. Sponsoring Agency Code FAA

15. Supplementary Notes

This research was conducted under Tas. AM-D-77-PSY-38.

16. Abstract

Illusions due to reduced visual cues at night have long been cited as contributing to the dangerous tendency of pilots to fly too low during night landing approaches. The cue of motion parallax (a difference in rate of apparent movement of objects in the visual field) is frequently suggested as contributing to visual judgments of glide path but has not been systematically studied in relation to the night approach problem. Thus, the present experiment examined the effect of varying levels of motion parallax from both radial and vertical motion on perception of the orientation of a runway relative to the ground. Under simulated nighttime conditions (only runway and approach lighting were visible), 16 nonpilots adjusted the apparent slant of a model runway to make it appear horizontal as the model moved toward them along a 3^{o} approach path from a simulated distance of 4.33 to 1.33 nautical miles. Simulated approach speeds of 62 and 125 knots were used. The rate at which the model rotated during slant adjustments varied between 5^{o} and 30^{o} per minute. The adjusted slant of the runway model with respect to the approach path (generated approach angle) was the dependent variable. The average generated approach angle for 256 trials was 0.5^{o}. This consistent and large deviation from 3^{o} (which would represent accurate perception) indicates the presence of strong illusions, is in agreement with the documented tendency of pilots to fly low approaches at night, and is explained in terms of the equidistance tendency and/or errors in perceiving the direction of the model in the visual field. The data also suggest that motion parallax in the runway image is neither a reliable nor an effective cue for the safe judgment of glide path at distances greater than 1.33 miles.

17. Key Words Aircraft Landing Visual Illusions Motion Parallax	18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	12	

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PERCEIVED ORIENTATION OF A RUNWAY MODEL IN NONPILOTS
DURING SIMULATED NIGHT APPROACHES TO LANDING

I. Introduction.

Visual illusions due to reduction of available visual information at night have long been blamed for the dangerous tendency of pilots to fly too low during night landing approaches (1,10,12,13,16,17,18,20,21). Studies of aircraft accidents emphasize the importance of this problem with the finding of a high proportion of accidents in night approaches and landings that are not associated with adverse weather conditions (13,16).

One of the visual cues most frequently suggested as contributing to visual judgments of glide slope, or angle approach, is relative motion parallax. This cue has not previously received parametric study in the context of the night approach problem. Relative motion parallax is defined as a difference in rate of apparent movement of objects in the visual field (5). In approaches to landing, all objects in the image of the ground plane appear to move directly away from the aim point in a complex pattern of apparent velocities, which is a function of glide slope angle and approach speed (7).

Threshold values of relative motion parallax for perception of depth between two objects have been found to be about 1 minute of arc per second of time (9,11). The threshold value increases with separation of objects up to the limiting case of the absolute threshold for motion of a single object in an otherwise homogeneous visual field. The absolute threshold for motion has been found to be about 10 seconds of arc per second (3,9). Although equivalent thresholds for effectiveness of relative motion parallax in perception of slant have not been determined, several studies suggest that motion parallax can enhance the perception of slant or shape of a surface when other cues to orientation or shape are present (2,4,19).

The present experiment was conducted to examine the effect of varying levels of relative motion parallax from both radial and vertical motion on perception of the orientation of a runway model with respect to the horizontal ground plane.

II. Method.

Subjects. Sixteen paid volunteer male nonpilots between 18 and 29 years of age served as subjects. All had at least 20/20 acuity in the right eye

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The author wishes to thank A. Howard Hasbrook and Professor Walter C. Gogel for valuable discussions during the preparation of this paper.

as measured with the Bausch and Lomb Orthorater. All experimental judgments were monocular (right eye) in this experiment.

Apparatus. A scale model was used to simulate the nighttime view of the lighting of a 170-ft by 6,000-ft runway with centerline and touchdown zone lights and a 3,000-ft-long ALSF-2 approach light system without sequenced strobe lights. This apparatus is described in the Appendix. The runway moved directly toward the subject's observation point from a position 3^{o} below the straight-ahead direction in the field of view. The lights of the model were visible over a range of simulated distances from 4.3 to 1.3 nautical miles. Slant of the model was varied by rotation in the vertical plane. Only the simulated runway and approach lighting were visible in the scene, and their intensity was adjusted by experienced pilots to a subjectively realistic level. Viewing was monocular, with the right eye, to eliminate binocular disparity, which is not an effective cue during approaches to landing (18).

Procedure. The model was constantly rotating in the vertical plane as it approached the subject during experimental trials. The subject's task was to control the direction of rotation to make the model appear horizontal by reversing the direction of rotation with a switch every time the model appeared to be rotating away from the horizontal orientation. The independent variables were simulated approach speed, which was 62 or 125 knots, and rate of rotation in the vertical plane, which was 5^{o}, 10^{o}, 20^{o}, or 30^{o} per minute. After practice, all rotation rates were presented twice in random order at one approach speed before trials at the other speed were given. The order of presentation of the two approach-speed conditions was reversed for half the subjects.

III. Results.

The adjusted slant of the model with respect to the approach path, angle θ (as defined in the Appendix) was the dependent variable and was measured continuously as a function of distance over the range of simulated distances from 4.33 to 1.33 nautical miles from threshold. The model was visible only in this distance range. The mean generated approach angle was obtained for the two 1-nautical-mile segments of each approach between simulated distances of 3.33 and 1.33 nautical miles. The mean values were subtracted from 3^{o} to obtain an error score for this segment. Scores were averaged over the two repetitions of a given combination of rotation rate and approach speed. A response of 3^{o} would have indicated accurate perception. All generated approach angles were much less than 3^{o}.

The mean generated approach angle for individual subjects ranged from 1.0^{o} to 0.2^{o} with a standard deviation of 0.25^{o}. The grand mean for all subjects was 0.5^{o}. This value represents an error of 2.5^{o}. Analyses of variance revealed that generated-approach-angle errors decreased by a

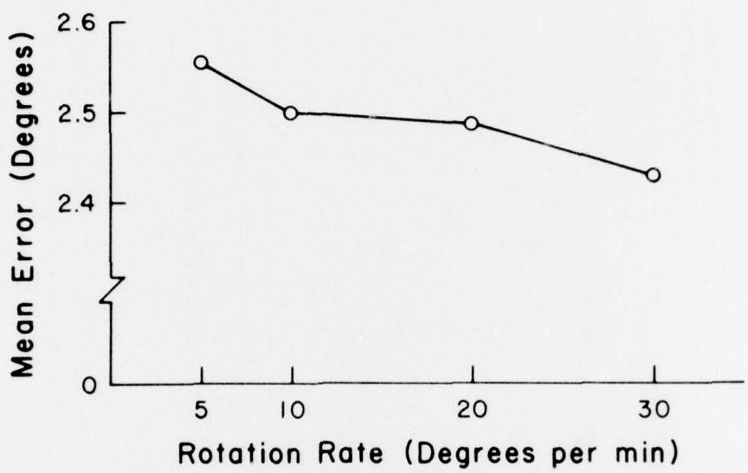

Figure 1. The effect of rotation rate on generated glide slope errors.

small statistically significant (p < .01) amount, about 0.14°, as rotation rate increased from 5° to 30° per minute, as shown in Figure 1. Approach speed had no significant effect on generated approach angle. Errors averaged over all subjects were only 0.02° higher at the 62-knot speed than at the 125-knot approach speed. There was, however, a significant (p < .05) second order interaction of approach speed with rotation rate and order of presentation of approach speeds. Figure 2 shows the interaction of approach speed with order at each of the four rotation rates. This interaction is due to generally greater errors among those subjects receiving the 125-knot speed first and a consistent increase in the magnitude of errors over the course of experimental trials in both order groups.

The difference between the highest and lowest generated-approach-angle values in each 1-nautical-mile segment was also measured for every trial. These range data are presented as a measure of the intrasubject variability of responses. Response variability was slightly but significantly (p < .01) greater in the farther distance segment, as shown in Figure 3a. The effect of rotation rate on response variability, as shown in Figure 3b, was significant (p < .01) and was about twice as great as the effect of rotation rate on the mean generated approach angle. A significant (p < .05) but small interaction of order by approach speed is shown in Figure 3c. This interaction indicates that variability decreased in the second half of the experiment.

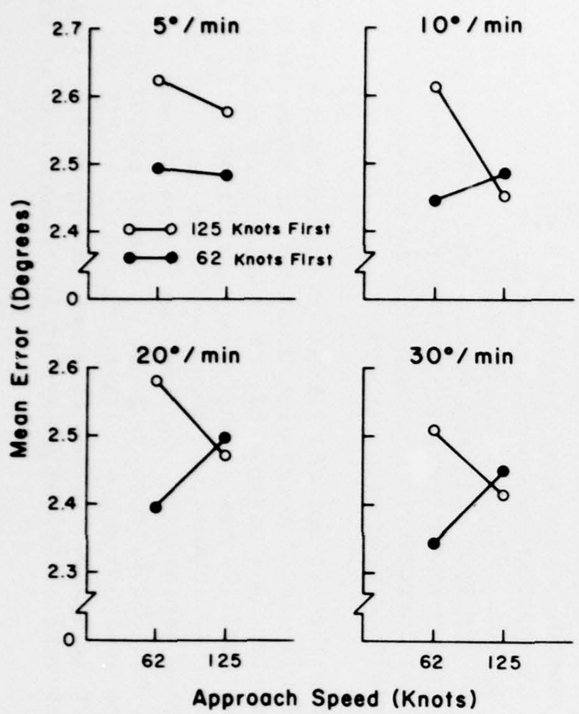

Figure 2. Generated glide slope errors as a function of the order by approach speed interaction at each rotation rate.

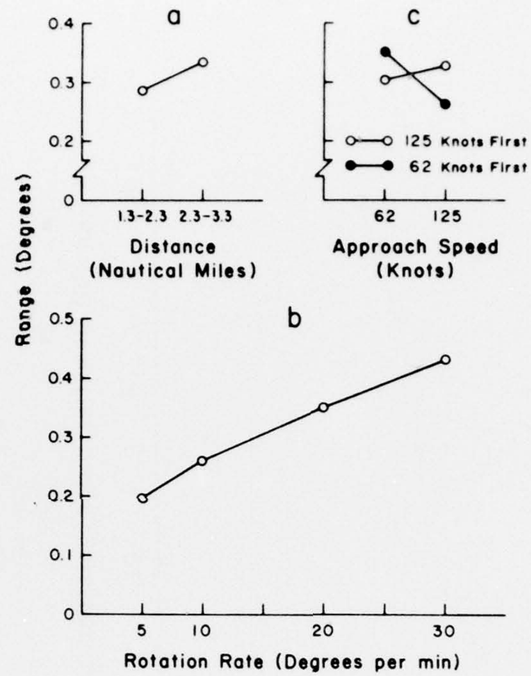

Figure 3. Variability (range) of generated glide slope responses as a function of (a) distance, (b) rotation rate, and (c) the order by approach speed interaction.

The above-mentioned effects, although statistically significant, were small relative to individual differences and, with the exception of the effect of rotation rate on response variability, were of the same order of magnitude as the error of measurement inherent in responses, about 0.1°.

IV. Discussion.

The present findings show that relative motion parallax has little effect on the perception of the orientation of the runway model by nonpilots at simulated distances as near as 1.33 nautical miles from runway threshold. The slight but statistically significant decrease in errors with increasing rotation rate might indicate a small effect of motion parallax that was due to motion in the vertical plane. It is also possible, however, that this small effect was caused by the increase in variability of responses with rotation rate. Regardless of the cause, the magnitude of the effect of rotation rate is probably not of practical significance. The conclusion that relative motion parallax is not an effective cue in this situation is subject to the following qualifications: (i) the possibility exists that the visual experience of pilots in actual approaches, where feedback does occur, may enhance sensitivity to relative motion parallax; (ii) in actual approaches, the image of the runway appears inside a visual frame provided by the visible parts of the cockpit window, and relative motions in the visual field between the runway image and frame may enhance the relative motion parallax cue. These two possibilities are presently being examined. Preliminary analyses suggest that flying experience and presence of a frame do not make relative motion parallax more effective. A third possibility that should receive attention is that values of relative motion parallax higher than those achieved in the present experiment might be more effective. Higher values would occur at distances of less than 1.33 nautical miles from threshold or with the presence of extra lights in the nighttime scene outside the runway.

The most important finding of the present experiment was that all observers in every stimulus condition consistently, systematically, and grossly misperceived the physical orientation of the runway model. Wulfeck, Queen, and Kitz (21) studied judgments of the horizontal orientation of an aircraft-carrier-deck lighting system that rotated in the vertical plane but did not move radially. The perceptual errors observed in their study were in the same direction as those of the present experiment but of lesser magnitude, since their subjects used binocular vision. As mentioned above, monocular vision was used in the present experiment because it is not normally effective in the approach-to-landing situation. The illusions observed in the present experiment occurred despite the presence of size cues and linear perspective in the runway image and a range of relative motion parallax values that is equivalent to or greater than that occurring naturally in landing approaches where only runway lights are visible. Judgments of this experiment concerned the geographical slant of the runway as distinguished from optical slant (6). Optical slant is defined as the slant of a surface relative to the line-of-sight to the surface; geographical slant is defined as slant of a surface relative to gravity. The perception of geographical slant involves both perception of optical slant and perception of angular position (or height) in the visual field relative to the straight-ahead direction.

Perceptual errors found in the present experiment are interpreted as indicating that the generated approach angles (i.e., optical slants of the runway when it was seen as horizontal) were perceptually overestimated and/or the direction of the model in the visual field was misperceived. Downward displacement of the judged direction of the horizon or corresponding errors in judged position of objects in a dark visual field is well documented (15). Overestimation of optical slant of the runway might occur as a consequence of a perceptual organizing process called the equidistance tendency (8). The equidistance tendency has been shown to make objects appear at the same distance to the extent that effective visual cues indicating a difference in distance are absent. Gogel (8) has cited several examples of reduction in apparent slant of stimuli with respect to a vertical reference plane as a function of cue reduction. Such effects are in the same direction as overestimation of slant with respect to a horizontal reference plane. Future research should measure the perceived direction of the runway relative to the apparent direction of the horizon and apparent magnitude of the generated approach angle in order to discriminate between overestimation of approach angle due to the equidistance tendency and errors due to misjudgment of visual direction. The role of a visible horizon should also be studied systematically in this context.

The present findings suggest that visual perception of the approach angle may be inaccurate during night approaches when only runway lights are visible. Pilots obviously can and usually do successfully correct for these errors because most night VFR approaches are performed safely. We should continue to study the method by which this correction occurs in order to understand why this critical process occasionally but tragically fails. The ineffectiveness of relative motion parallax as a cue when only runway lights are visible may be an important part of this problem.

References

1. Cocquyt, P.: Sensory Illusions, SHELL AVIATION NEWS, 178:19-24, 1953.

2. Cibis, P. A., S. J. Gerathewohl, and D. Rubenstein: Depth Perception in Monocular and Binocular Vision. Special Report. USAF School of Aviation Medicine, Randolph Field, Texas, January 1953.

3. Fox, J. N.: Perception of Real and Apparent Motion of Two Objects in a Structureless Visual Field, Ann Arbor, Michigan, University Microfilms, 1967, 124 p.

4. Gibson, E. J., J. J. Gibson, O. W. Smith, and H. Flock: Motion Parallax as a Determinate of Perceived Depth, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 58:40-51, 1959.

5. Gibson, J. J.: The Perception of the Visual World, Cambridge, Massachusetts, Riverside Press, 1950, pp. 117-136.

6. Gibson, J. J., and J. Cornsweet: The Perceived Slant of Visual Surfaces-Optical and Geographical, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 44:11-15, 1952.

7. Gibson, J. J., P. Olum, and F. Rosenblatt: Parallax and Perspective During Aircraft Landings, AMERICAN JOURNAL OF PSYCHOLOGY, 68:372-385, 1955.

8. Gogel, W. C.: Equidistance Tendency and Its Consequences, PSYCHOLOGICAL BULLETIN, 64:153-163, 1965.

9. Graham, C. H.: Vision and Visual Perception, New York, Wiley, 1965, pp. 511-516.

10. Hartman, B. O., and G. K. Cantrell: Psychological Factors in "Landing Short" Accidents, FLIGHT SAFETY, 2:26-32, 1968.

11. Harvey, L. O., Jr., and J. A. Michon: Detectability of Relative Motion as a Function of Exposure Duration, Angular Separation, and Background, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 103:317-325, 1974.

12. Hasbrook, A. H.: Anatomy of a Landing Cue by Cue, BUSINESS AND COMMERCIAL AVIATION, 29:54-60, 1971.

13. Hasbrook, A. H.: The Approach and Landing: Cues and Clues to a Safe Touchdown, BUSINESS AND COMMERCIAL AVIATION, 32:39-43, 1975.

14. Hochberg, J., and O. Smith: Landing Strip Markings and the "Expansion Pattern": I. Program, Preliminary Analyses, and Apparatus, PERCEPTUAL AND MOTOR SKILLS, 5:81-92, 1955.

15. Howard, I. P., and W. B. Templeton: Human Spatial Orientation, New York, Wiley, 1966, pp. 280-289.

16. Kraft, C. L.: Measurement of Height and Distance Information Provided Pilots by the Extra-Cockpit Visual Scene. In: Visual Factors in Transportation Systems: Proceedings of Spring Meeting, 1969. Committee on Vision, National Academy of Sciences--National Research Council, Washington, D.C., 1969.

17. Kuhlman, R. L.: Approach With Care, FLYING, 78:88-90, 1966.

18. Pitts, D. G.: Visual Illusions and Aircraft Accidents. USAF School of Aerospace Medicine Division (AFSC). Brooks Air Force Base, Texas, Report No. SAM-TR-67-28, 1967.

19. Slocum, R. V., and W. A. Hershberger: Perceived Orientation in Depth from Line-of-Sight Movement, PERCEPTION AND PSYCHOPHYSICS, 19:176-182, 1976.

20. Vinacke, W. E.: Illusions Experienced by Aircraft Pilots While Flying, JOURNAL OF AVIATION MEDICINE, 18:308-325, 1947.

21. Wulfeck, J., J. E. Queen, and W. M. Kitz: The Effect of Lighted Decks Shape on Night Carrier Landing. Technical Report No. 196-115. Dunlap and Associates, Inc., Inglewood, California, October 1974.

APPENDIX

Description of Apparatus

The basic concept of the apparatus was a moving runway model of variable slant as suggested by Hochberg and Smith (14). Added to their concept was a technique for modeling night runway lighting and an optical system for varying position of the model in the visual field, both of which were developed by the author. A technique for precise control and measurement of model slant, developed by Wulfeck, Queen, and Kitz (21), was also adapted for this apparatus.

Runway Model. The runway model was based on a 243.8-cm-long by 15.2-cm-wide light box. Its removable Formica top was penetrated by short fiber optic strands to simulate runway lights. The fiber optic strands were 0.508 mm in diameter, 6 mm in length, and cut off with a 45° angle on one end. The angled surface of each fiber was adjusted to protrude just above the Formica surface and to point toward the direction of the observation position. Red and green simulated lights were produced by gluing transparent plastic over the appropriate fibers on the underside of the light box top. The top surface of the light box was painted flat black. The sources were two parallel 243.84-cm instant-start fluorescent tubes (General Electric F96T12 - CWX, Deluxe Cool White) mounted 2.54 cm below the top of the light box and separated from each other by 2.54 cm laterally. One side of each fluorescent tube was covered with tape and painted black to make it opaque. As the tubes were mounted with a single pin on each end, they could be rotated to expose varying amounts of the unpainted sides to vary the amount of light reaching the fiber optic strands and, hence, the brightness of the simulated runway and approach lights. The brightness of lights was adjusted by experienced pilots to appear realistic. In the prototype model, fibers were glued in holes drilled in the pattern of a runway 6,000 ft (1828.8 m) long by 170 ft (51.8 m) wide with centerline and touchdown zone lighting and an ALSF-2 approach light system 3,000 ft (914.4 m) long. The model scale was 1,200 to 1.

Vertical Motion System. The runway model was mounted on a cart, C in Figure A-1, so that a transverse horizontal axis of rotation F, which was perpendicular to the longitudinal axis of the runway, passed through the plane of the simulated runway. The model could be rotated 20° from a physically horizontal orientation in either direction but was limited to rotation from the horizontal position to 20° toward the observation point when viewing involved the mirror system to be described below. The rotation of the model was controlled by a chain-drive mechanism. The chain was connected to both ends of the light box and was driven at a constant rate by a Boston Gear Works 1/12-hp ratiomotor and model R12 speed control that gave almost instant starting and stopping. Rates of rotation in the vertical plane of from 0° to more than 30° per minute could be produced.

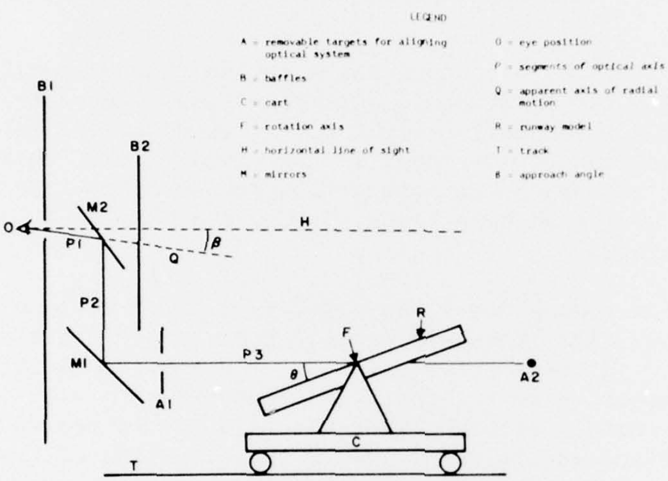

Figure A-1. Schematic diagram of apparatus.

Guide sprockets for the chain were located directly below the ends of the light box to prevent bouncing of the light box when the direction of rotation was reversed at high-rotation rates. A center-tapped Beckman model SA2880 10-turn potentiometer with 0 to 20,000 ohms of resistance and 0.05 percent linearity was mounted on the same shaft as the sprocket that drove the chain. This potentiometer was used in conjunction with a regulated power supply to give a remote indication of model slant as a function of time as the model moved toward the observation position at a constant rate. Both a digital voltmeter and a recorder could be used to indicate model slant to the nearest 0.1°. A dial indicator and vernier graduated in 0.1° units (PIC Design Corp., catalog number AX4) was mounted on the shaft on which the model rotated. This instrument was used in conjunction with a machinist's level for calibration of electrical slant indicators.

Radial Motion System. The runway model with its rotation system was mounted on a cart that moved along a level track T toward the observation position. A chain driven by a Graham variable speed transmission, model KFS, with a 1/4-hp motor pulled the cart along at a constant scale speed that was adjustable (e.g., 0 to 250 knots for the 1,200 to 1 scale model described above). The cart rode on ball-bearing wheels on a graduated two-rail Gaertner Scientific Co. optical bench track 8.0 meters long. This allowed the 1,200 to 1 scale model to move over a range of simulated distances from approximately 4.33 nautical miles to 1.33 nautical miles. Larger models could be used to simulate nearer distances. A third rail located 0.9 meters to the side was used with an outrigger on the cart to give lateral stability during radial motion of the cart. Microswitches were placed along the track to turn the model lights on and off at the appropriate points in order to make the model visible or remove it from view. A solid-state logic system was used in conjunction with various microswitches on the track and the rotation system to control lights, radial motion, and rotation of the model during experiments.

Optical System. To have the axis of rotation of the model (F in Figure 1) move radially along an apparent line-of-sight Q at a constant selectable angle β with respect to a horizontal line-of-sight H, an optical system consisting of mirrors M1 and M2 was constructed. Mirror M1 was oriented at 45^{o} with respect to the horizontal axis of radial motion of the model. Mirror M2 could be varied systematically in height and slant with respect to M1 by a simple system of removable pegs in the wall of the mirror holder so that the segment of the optical axis P1 could be reflected to the eye at a number of discrete viewing angles β measured with respect to H while maintaining coincidence of P3 and the axis of radial motion of the model. For this alignment, sighting targets T1 and T2 were temporarily installed at end points on the track at the exact height of the radial motion axis to allow fine adjustments of mirrors. With targets T1 and T2 aligned visually from the observation point O, the value of β was checked with a theodolite. Fine adjustments of mirrors were made with shims. When the model was physically horizontal, it was parallel to the line of sight and was visible only as a thin horizontal line. When the model was moving toward the observation point and slanted physically 3^{o} toward the observation position with its near end down (β was 3^{o}), the apparatus produced an image identical to that of viewing a physically level runway during a constant 3^{o} approach to landing. Simulated runway size and distance were related to the corresponding physical measurements of the apparatus by the scale factor of the model. The angle of the model's surface with respect to the observer's line-of-sight and the angular position of the model in the visual field were identical to the corresponding angles in the simulated scene. Equations for determining motion parallax between components of the scene are given by Gibson, Olum, and Rosenblatt (7) and Hochberg and Smith (14).

The observation position was an enclosed ventilated booth. A head and chin rest was used to steady the subject's head in front of the viewing aperture B1. Viewing was monocular to eliminate binocular disparity, which is not an effective cue during approaches to landing (18). Baffle B2 was used for control of extraneous light. A pushbutton or toggle switch was used by the subject for control of model rotation during experimental trials. A manual shutter operated by the experimenter was used to occlude the viewing aperture when desired.

Three important advantages of this visual simulation technique are (i) excellent optical resolution, (ii) the preservation of the natural relation of distance to apparent brightness of light sources that are effectively point sources (i.e., they subtend less than 1.25 minute of arc at the eye), and (iii) the ability to vary visual direction of the radial motion axis without a complex computer for synchronizing simulated attitude and distance changes. These characteristics are essential for a display intended for study of size cues (including relative size and linear perspective), relative motion parallax, and brightness gradient as cues to space perception in the night approach situation. In addition to study of these cues, this apparatus can also be used for studying of the effect of training on the judged orientation of the model and on the memory processes involved in these judgments. The apparatus described above is thought to be a useful device for study of space perception in general and may be used for study of judgments of attitude, distance, and runway characteristics as well as perception of runway slant and approach angle.